attempt at explanation—while everyone of them might have been made part of his nature for ever afterwards, by giving the simple reason in each case—if he does not doubt the competence of his teacher, will have no more to do with him.

La Spectroscopie. By A. Cazin. (Paris: Gauthièr-Villars.)

THE talented author of this work has passed away since the MS. was completed. This is by no means a systematic treatise, but it contains a large amount of information—some of it out-of-the-way information—and it will repay perusal. As much of M. Cazin's information on the celestial applications has been gathered from Secchi's works its complete accuracy is not to be relied on, but the explanation given of the different methods employed is very clear.

The part of the book which perhaps will be read with the greatest interest is that dealing with radiation and absorption spectra. In this part the author includes a notice of much of his own work, which is of great interest and importance. The *historique* of the question as to the existence of double or multiple spectra is interesting, and the author's leaning is against the view held by Ångström and Thalèn. He gives special observations of his own concerning nitrogen, and indeed was engaged on an extension of them at the time of his lamented death.

LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts. No notice is taken of anonymous communications.*

[*The Editor urgently requests correspondents to keep their letters as short as possible. The pressure on his space is so great that it is impossible otherwise to ensure the appearance even of communications containing interesting and novel facts.*]

Sun-spots and Rainfall

IF the sun-spot cycles were all of the same length the simplest way of comparing the yearly sun-spot areas with the yearly amounts of rainfall in order to see whether the two phenomena were more or less numerically related, would be to find the annual means of the greatest possible number of cycles, care being taken to place the years of maximum and minimum in the same two groups respectively, and the intervening years in due succession. But as the sun-spot cycles are not of the same length, we must in employing the method of arithmetical means, make some modifications calculated to suit the circumstances of the case.

1. We may, for example, take any cycle whatever may be its duration, and commencing with its first and ending with its last year, compare with the sun-spots the rainfall at any station, or the means of the rainfall at a number of stations for the same years.

2. If some of the cycles be of the same length, we may take these alone and compare them with the rainfall, still taking care that the years of maximum and minimum sun-spots shall be respectively in the same groups.

3. The average length of the sun-spot cycle being, as far as is yet known, about eleven years, we may take any number of cycles of different lengths and make two separate comparisons, in one of which the maximum years are to be placed in the same group, and in the other the minimum years in the same group, the number of the other groups preceding and following the epochal groups being determined by the fact that the mean interval from minimum to maximum is about 3·7 years, and from maximum to minimum about 7·4 means.

I have tried these and several other methods, with, I think, considerable success. The method just mentioned (3), which is the old one of arithmetical means somewhat modified to meet the conditions of the case, possesses several advantages, one of the most important of which is that it enables us to compare directly the rainfall with the sun-spots in the epochal years, and in at least two years before and two years after them, thus affording a fair comparison for nearly the whole cycle of eleven years—a most essential point, which, it would appear, has been overlooked by some writers on the subject.

Having in my last communication (NATURE, vol. xvii. p. 448) given an example of the first half of the above method, together with the results obtained by it for several localities, I intended on this occasion to submit only one or two examples of the second half. But finding that the method has been criticised by Mr. Buchan, and having now Prof. Wolf's latest edition of his relative sun-spot numbers, as well as the rainfall of Madras for 1877, it may be proper to give instances of the application of the whole process.

Let us begin with Wolf's relative numbers, which are so arranged in the following table that those for the years of maximum sun-spot, from 1811 to 1877, are all in the sixth line. This table has already been given by Mr. Buchan (NATURE, vol. xvii. p. 506), but as references will be made to it now, and also in future discussions of the rainfalls of various parts of the globe, it is desirable to reproduce it here.

TABLE I.—*Wolf's Sun-spot Numbers (Maximum Years in Sixth Line).*

Year.	1811–1823.	1824–1836.	1832–1844.	1843–1855.	1855–1867.	1865–1877.	Means.	Mean Cycle.	Variation.	Year of Cycle.
1	1·6	8·1	26·3	13·1	7·7	31·4	14·7	—	—	—
2	4·9	16·2	9·4	19·3	5·1	14·7	11·6	14·9	− 33·9	1
3	12·6	35·0	13·3	38·3	22·9	8·8	21·8	25·4	− 23·4	2
4	16·2	51·2	59·0	59·6	56·2	36·8	46·5	48·8	0·0	3
5	35·2	62·1	119·3	97·4	90·3	78·6	80·5	77·0	+ 28·2	4
6	**46·9**	**67·2**	**136·9**	**124·9**	**94·8**	**131·8**	**100·4**	**91·9**	**+ 43·1**	**5**
7	39·9	67·0	104·1	95·4	77·7	113·8	83·0	83·0	+ 34·2	6
8	29·7	59·4	83·4	69·8	61·0	99·7	65·7	65·6	+ 16·8	7
9	23·5	26·3	61·8	63·2	45·4	67·7	48·0	49·0	+ 0·2	8
10	16·2	9·4	38·5	52·7	45·2	43·1	34·2	34·6	− 14·2	9
11	6·1	13·3	23·0	38·5	31·4	18·9	21·9	24·6	− 24·2	10
12	3·9	59·0	13·1	21·0	14·7	11·3	20·5	22·5	− 26·3	11
13	2·6	119·3	19·3	7·7	8·8	7·0	27·5	—	—	—

It will be seen that each of six of the columns in the above table gives the sun-spot numbers for thirteen years, and that the first term of what is called the "mean cycle" is obtained from the expression, $\frac{a + 2b + c}{4}$, where a, b, c, are the means of the sun-spots for the first, second, and third years of the thirteen years, the remaining terms being obtained in a similar manner. The "variation" is simply the deviations from the mean value of the sun-spots for the "mean cycle."

The next table gives the sun-spot numbers, from 1816 to 1872, arranged so that the minimum years are in the eighth line:—

TABLE II.—*Wolf's Sun-spot Numbers (Minimum Years in Eighth Line).*

Year.	1816–1828.	1826–1838.	1836–1848.	1849–1861.	1860–1872.	Means	Mean Cycle.	Variation.	Year of Cycle.
1	46·9	35·0	119·3	95·4	94·8	78·3	—	—	—
2	39·9	51·2	136·9	69·8	77·7	75·1	73·1	+ 23·3	1
3	29·7	62·1	104·1	63·2	61·0	64·0	64·3	+ 14·5	2
4	23·5	67·2	83·4	52·7	45·4	54·4	54·6	+ 4·8	3
5	16·2	67·0	61·8	38·5	45·2	45·7	44·2	− 5·6	4
6	6·1	59·4	38·5	21·0	31·4	31·3	30·8	− 19·0	5
7	3·9	26·3	23·0	7·7	14·7	15·1	17·3	− 32·5	6
8	**2·6**	**9·4**	**13·1**	**5·1**	**8·8**	**7·8**	**12·7**	**− 37·1**	**7**
9	8·1	13·3	19·3	22·9	36·8	20·1	24·4	− 25·4	8
10	16·2	59·0	38·3	56·2	78·6	49·7	51·6	+ 1·8	9
11	35·0	119·3	59·6	90·3	131·8	87·2	80·7	+ 30·9	10
12	51·2	136·9	97·4	94·8	113·8	98·8	94·6	+ 44·8	11
13	62·1	104·1	124·9	77·7	99·7	93·7	—	—	—

We can now compare the rainfall of Madras with the values of the sun-spots in Tables I. and II., except for the years 1811 and 1812, for which there are no observations:—

TABLE III.—*Rainfall of Madras (Maximum Years in Sixth Line).*

Year.	1811–1823.	1824–1836.	1832–1844.	1843–1855.	1855–1867.	1865–1877.	Means.	Mean Cycle.	Variation.	Year of Cycle.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	
1	—	33.7	18.4	*50.3	32.3	41.6	35.3	—	—	—
2	—	56.0	*37.1	65.4	*47.0	51.4	51.4	45.3	− 3.2	1
3	45.1	60.7	39.0	38.1	52.9	*24.4	43.4	48.3	− 0.2	2
4	32.4	88.4	41.5	79.8	48.5	41.4	55.3	51.3	+ 2.8	3
5	56.0	37.9	44.8	81.0	55.1	32.3	51.2	51.2	+ 2.7	4
6	**41.2**	**36.9**	**49.3**	**54.8**	**27.6**	**74.1**	**47.3**	**48.1**	**− 0.4**	**5**
7	63.6	32.4	52.3	39.8	37.2	56.3	46.9	48.7	+ 0.2	6
8	76.2	44.3	53.1	36.9	38.2	73.7	53.7	50.4	+ 1.9	7
9	36.3	18.4	58.6	64.3	54.6	51.8	47.3	51.5	+ 3.0	8
10	70.0	*37.1	58.3	72.7	47.2	62.9	58.0	50.7	+ 2.2	9
11	47.1	39.0	36.5	35.8	41.6	37.1	39.5	45.4	− 3.1	10
12	59.6	41.5	*50.3	43.2	51.4	21.5	44.6	42.1	− 6.4	11
13	*26.6	44.8	65.4	32.3	*24.4	45.0	39.7	—	—	—

The "mean cycle" in the above table has been formed (in the way already mentioned) with the view of reducing the effects of what are called "accidental" irregularities in the rainfall, and its mean value is 48.5 inches, while the mean of the thirteen "means" is 47.3 inches. Now it will be observed that, as was the case when only the years 1813 to 1867 were taken (NATURE, vol. xvii. p. 449), there is apparently a double oscillation of the Madras rainfall during the sun-spot cycle. It will be seen also—and it is important to bear this point in mind—that the mean rainfall of the seven maximum years not only does *not* exceed, but barely reaches, the mean for the whole cycle. There are apparently two maxima and two minima, and one of the minima seems to occur very soon after the sun-spot maximum. In fact, there was a great deficiency of rainfall at Madras in the maximum year 1860, and in the years 1830, 1861, and 1869, immediately following or preceding a maximum year, but whether there were famines in one or more of these years, I do not know. (The years of minimum sun-spots are marked with an asterisk.)

Coming now to the second half of the method, so far as Madras is concerned, we get the following results:—

TABLE IV.—*Rainfall of Madras (Minimum Years in Eighth Line).*

Year.	1816–1828.	1826–1838.	1836–1848.	1849–1861.	1860–1872.	Means	Mean Cycle.	Variation.	Year of Cycle.
	in.	in.	in.	in.	in.	in.	in.	in.	
1	*41.2	60.7	44.7	39.8	*27.6	42.8	—	—	—
2	63.6	88.4	*49.3	36.9	37.2	55.1	51.7	+ 2.7	1
3	76.2	37.9	52.3	64.3	38.2	53.8	52.3	+ 3.3	2
4	36.3	*36.9	53.1	72.7	54.6	50.7	51.0	+ 2.0	3
5	70.0	32.4	58.6	35.8	47.2	48.8	48.8	− 0.2	4
6	47.1	44.3	58.3	43.2	41.6	46.9	45.5	− 3.5	5
7	59.6	18.4	36.5	32.3	51.4	39.6	40.8	− 8.2	6
8	**26.6**	**37.1**	**50.3**	**47.0**	**24.4**	**37.1**	**40.0**	**− 9.0**	**7**
9	33.7	39.0	65.4	52.9	41.4	46.5	43.3	− 5.7	8
10	56.0	41.5	38.0	48.5	32.3	43.4	49.0	0.0	9
11	60.7	44.8	79.8	55.1	*74.1	62.9	57.4	+ 8.4	10
12	88.4	*49.3	81.0	*27.6	56.3	60.5	58.8	+ 9.8	11
13	37.9	52.3	*54.8	37.2	73.7	51.2	—	—	—

The above table shows that the minimum rainfall, both for the "means" and the "mean cycle," coincides with the minimum of sun-spots (see Table II.), and that, upon the whole, the spots and the rain decrease and increase together. But as the maximum years (with an asterisk) are not all in the same line, nor the minimum years in Table III., all in the same line, it is necessary to confine our attention to the results for about two years on either side of the epochal years in Tables III. and IV., and in doing so we find evidence of a double oscillation.

To ascertain whether there is some probability of such an oscillation in the rainfall of Madras, we must have recourse to the more efficient method of the harmonic analysis. I have not had leisure to do so in this particular case, but Mr. J. Allan Broun (NATURE, vol. xvi. p. 334), in a thorough examination of the rainfalls of Madras and Trevandrum for the years 1838-76, gives for the mean oscillations of the Madras rainfall during that period the following equation, where y is the mean yearly rainfall in inches:—

$$y = 5.4 \sin(\theta + 50^\circ) + 4.6 \sin(2\theta + 252^\circ);$$

and he remarks that these angles give the epochs of *minimum* rainfall both in the years of minimum and of maximum sunspots, and that the single oscillation (of about five years) has held good in seven successive periods. Now this is nearly what we should expect from Tables III. and IV.

Leaving the Madras rainfall for the present, let us come to that of Edinburgh for the years 1824 to 1872. The following table gives a comparison of the Edinburgh rainfall with the sun-spots from 1824 to 1867:—

TABLE V.—*Rainfall of Edinburgh (Maximum Years in Sixth Line).*

Year.	1824–1836.	1832–1844.	1843–1855.	1855–1867.	Means	Mean Cycle.	Rain Var.	Spot Var.	Year of Cycle.
	in.	in.	in.	in.	in.	in.	in.		
1	24.8	23.2	*23.8	20.3	23.0	—	—	—	—
2	22.1	*20.9	20.9	*28.5	23.1	22.8	− 2.8	− 37.2	1
3	15.3	21.0	26.6	24.9	22.0	23.8	− 1.8	− 22.8	2
4	32.6	25.2	31.5	24.3	28.4	26.3	+ 0.7	+ 4.4	3
5	25.2	33.0	22.8	25.9	26.7	28.0	+ 2.4	+ 33.0	4
6	**30.0**	**26.8**	**30.6**	**33.4**	**30.2**	**28.9**	**+ 3.3**	**+ 43.8**	**5**
7	33.2	31.0	22.2	28.6	28.8	28.4	+ 2.8	+ 32.9	6
8	24.5	23.4	21.3	33.9	25.8	26.1	+ 0.5	+ 14.3	7
9	23.2	25.5	22.8	25.6	24.3	25.2	− 0.4	− 2.9	8
10	*20.9	26.2	31.5	28.1	26.7	24.6	− 1.0	− 16.6	9
11	21.0	16.9	[1]21.8	23.6	20.8	23.1	− 2.5	− 24.7	10
12	25.2	*23.8	20.9	27.2	24.3	23.9	− 1.7	− 24.0	11
13	33.0	20.9	20.3	*31.0	26.3	—	—	—	—

An inspection of the above table will show that there is a remarkable coincidence between the rainfall and sun-spot variations—much more remarkable than at Madras. The years of maximum and minimum rainfall and sun-spot for the mean cycles coincide, and, on the whole, there is a regular gradation from minimum to maximum and from maximum to the next minimum.

The next table (the second half of the process for Edinburgh) gives almost equally remarkable results.

TABLE VI.—*Rainfall of Edinburgh (Minimum Years in Eighth Line).*

Year.	1826–1838.	1836–1848.	1849–1861.	1860–1872.	Means	Mean Cycle.	Rain Var.	Spot Var.	Year of Cycle.
	in.	in.	in.	in.	in.	in.	in.		
1	15.3	33.0	22.2	*33.4	26.0	—	—	—	—
2	32.6	*26.8	21.3	28.6	27.3	27.2	+ 1.2	+ 24.7	1
3	25.2	31.0	22.8	33.9	28.2	27.8	+ 1.8	+ 15.9	2
4	*30.0	23.4	31.5	25.6	27.6	27.6	+ 1.6	+ 5.6	3
5	33.2	25.5	21.8	28.1	27.2	26.4	+ 0.4	− 5.4	4
6	24.5	26.2	20.9	23.6	23.8	24.1	− 1.9	− 20.4	5
7	23.2	16.9	20.3	27.2	21.9	23.4	− 2.6	− 36.3	6
8	**20.9**	**23.8**	**28.5**	**31.0**	**26.0**	**24.4**	**− 1.6**	**− 42.1**	**7**
9	21.0	20.9	24.9	28.6	23.8	24.6	− 1.4	− 28.6	8
10	25.2	26.6	24.3	22.2	24.6	25.2	− 0.8	+ 2.9	9
11	33.0	31.5	25.9	*22.1	28.1	26.8	+ 0.8	+ 35.3	10
12	*26.1	22.8	*33.4	23.2	26.4	28.2	+ 2.2	+ 48.9	11
13	31.0	*30.6	28.6	38.2	32.1	—	—	—	—

We find from the preceding table that the year of minimum rainfall was, on an average, the year immediately before the year of minimum sun-spot, and that the year of maximum sun-spot coincided with the year of maximum rainfall. Another coincidence is that the ratio of the rainfall to the sun-spots in the eleventh year of the "mean cycle" is nearly the same as the corresponding ratio in the first year of the cycle. Whether these relations are constant is another question; in a case of

[1] Interpolated.

this kind we can scarcely venture to go beyond actual experience.

It would be easy to multiply similar examples and results of the method which I ventured to submit in my former paper to NATURE—a method the main object of which was to refer, as nearly as possible (without using the more laborious method of the harmonic analysis), the rainfalls of remote localities to the epochs of maximum and minimum sun-spots. I will, however, for the present only give, further, the results that have been obtained for the Paris rainfall from 1824 to 1867, and from 1816 to 1870.

TABLE VII.—*Rainfall of Paris* (*Maximum Years in Sixth Line*).

Year.	1824–1836.	1832–1844.	1843–1855.	1855–1867.	Means	Mean Cycle.	Rain Var.	Spot Var.	Year of Cycle.
	m.	m.	m.	m.	m.	m.	m.		
1	572	456	*542	344	478	—	—	—	—
2	469	*503	571	*565	527	502	− 11	− 37·2	1
3	410	421	581	492	476	493	− 20	− 22·8	2
4	501	438	564	466	492	501	− 12	+ 4·4	3
5	585	611	430	545	543	541	+ 28	+ 33·0	4
6	**560**	**547**	**575**	**655**	**584**	**563**	**+ 50**	**+ 43·8**	**5**
7	573	542	597	458	543	554	+ 41	+ 32·9	6
8	529	580	563	516	547	522	+ 9	+ 14·3	7
9	456	455	469	426	452	487	− 26	− 2·9	8
10	*503	527	597	366	498	472	− 41	− 16·6	9
11	421	342	454	542	440	484	− 29	− 24·7	10
12	438	*542	614	644	559	520	+ 7	− 24·0	11
13	611	571	344	*565	523	—	—	—	—

The above table shows that, whether we take the "means" or the "mean cycle," the rainfall was greatest in the years of maximum sun-spot; that it was least in the ninth year of the "mean cycle;" and that, on the whole, the rainfall and sun-spots, notwithstanding some discrepancies, increased and decreased together.

The next table, in which the arrangement is inverted, gives similar results for Paris.

TABLE VIII.—*Rainfall of Paris* (*Minimum Years in Eighth Line*).

Year.	1816–1828.	1826–1833.	1836–1848.	1849–1861.	1860–1872.	Means	Mean Cycle.	Rain Var.	Spot Var.	Year of Cycle.
	m.	m.	m.	m.	m.	m.	m.	m.		
1	*546	410	611	597	*655	564	—	—	—	—
2	565	501	*547	563	458	527	531	+ 20	+ 23·3	1
3	432	585	542	469	516	509	525	+ 14	+ 14·5	2
4	615	*560	580	597	426	556	516	+ 5	+ 4·8	3
5	378	573	455	454	366	445	501	− 10	− 5·6	4
6	584	529	527	614	542	559	501	− 10	− 19·0	5
7	424	456	342	344	644	442	492	− 19	− 32·5	6
8	**457**	**503**	**542**	**565**	**565**	**526**	**502**	**− 9**	**− 37·1**	**7**
9	572	421	571	492	512	514	510	− 1	− 25·4	8
10	469	438	581	466	477	486	499	− 2	+ 1·8	9
11	410	611	564	545	*418	510	510	− 1	+ 30·9	10
12	501	*547	430	*655	—	533	529	+ 17	+ 44·8	11
13	585	542	*575	458	—	540	—	—	—	—

We see that the minimum rainfall occurred, on an average, in the year immediately preceding the year of minimum sun-spots, as at Edinburgh, but that the variation was not so regular.

As formerly remarked, the rainfalls of Edinburgh and Paris—especially that of Edinburgh—are more favourable to the theory than the rainfall of Madras.

Mr. Buchan considers the method which has now been sketched a new one, and, "as such, deserving of a careful examination as to how far it is applicable to the data submitted for discussion." This examination consists almost wholly in showing that by placing the maximum years in the same line or group the minimum years are spread over six out of thirteen groups, and that by placing the minimum years in the same group the maximum are also spread over six groups. Hence he concludes that this double arrangement is inferior to a single one in which the maximum and minimum years together are "compactly" spread over six out of eleven groups. But it seems to me that he has in great measure lost sight of what should be a main object of comparison of sun-spots and rainfall, namely, the closest possible reference of the rainfall to the *epochs* of maximum and minimum sun-spots, and that however compact the arrangement he recommends may be considered, it is fundamentally objectionable. By placing the maximum and minimum years respectively in the *same* groups there is certainly a much greater chance of finding any connection that may exist between the two phenomena than by spreading them over six groups out of eleven.

How far the method defended by Mr. Buchan is applicable to the data will appear from the following table of the Madras rainfall, in which Dr. Hunter's arrangement is adopted. The maxima and minima years are marked with an asterisk.

TABLE IX.—*Rainfall of Madras* (*Maximum and Minimum Years in Six Groups*).

Year.	1811–1821.	1822–1832.	1833–1843.	1844–1854.	1855–1865.	1866–1876.	Means	Rain Var.	Spot Var.
	in.	in.	in.	in.	in.	in.	in.		
1	—	59·6	*37·1	65·4	32·3	51·4	49·2	+ 0·9	− 37·6
2	—	*26·6	39·0	38·1	*47·0	*24·4	35·0	− 13·3	− 35·0
3	45·1	33·7	41·5	79·8	52·9	41·4	49·1	+ 0·8	− 14·2
4	32·4	56·0	44·8	81·0	48·5	32·3	49·2	+ 0·9	+ 16·6
5	56·0	60·7	49·3	*54·8	55·1	*74·1	58·3	+ 10·0	+ 45·0
6	*41·2	88·4	52·3	39·8	*27·6	56·3	50·9	+ 2·6	+ 37·0
7	63·6	37·9	53·1	36·9	37·2	73·7	50·4	+ 2·1	+ 24·5
8	76·2	*36·9	58·6	64·3	38·2	51·8	54·3	+ 6·0	+ 11·0
9	36·3	32·4	58·3	72·7	54·6	62·9	52·9	+ 4·6	− 2·4
10	70·0	44·3	36·5	35·8	47·2	37·1	45·1	− 3·2	− 15·4
11	47·1	18·4	*50·3	43·2	41·6	21·5	37·0	− 11·3	− 29·2

The mean rainfall for the cycle is 48·3 inches. Now the mean rainfall for the fifth group is 58·3 inches, and the mean value of the sun-spots for the same group 45·0, which is the *maximum*. It is thus made to appear that, on an average, the maximum rainfall of Madras coincides with the maximum of sun-spots. But this is contrary to fact. We know, as a matter of observation (see Table III.), that the mean rainfall of Madras in the maximum years was not above the average, and yet the arrangement recommended by Mr. Buchan makes it *ten* inches *above* the average.

Applying the same arrangement to the rainfall of Edinburgh, we get the following results.

TABLE X.—*Rainfall of Edinburgh* (*Maximum and Minimum Years in Six Groups*).

Year.	1822–1832.	1833–1843.	1844–1854.	1855–1865.	Mean Rain.	Mean Spots.	Rain Var.	Spot Var.
	in.	in.	in.	in.	in.		in.	
1	26·1	*20·9	20·9	20·3	22·1	8·1	− 3·6	− 43·2
2	*30·3	21·0	26·6	*28·5	26·6	14·8	+ 0·9	− 36·5
3	24·8	25·2	31·5	24·9	26·6	37·4	+ 0·9	− 13·9
4	22·1	33·0	22·8	24·3	25·6	72·3	− 0·1	+ 21·0
5	15·3	*26·1	*30·6	25·9	24·5	92·4	− 1·2	+ 41·1
6	32·6	31·0	22·2	*33·4	29·8	86·4	+ 4·1	+ 35·1
7	25·2	23·4	21·3	28·6	24·6	73·2	− 1·1	+ 21·9
8	*30·0	25·5	22·8	33·9	28·0	63·3	+ 2·3	+ 12·0
9	33·2	26·2	31·5	25·6	29·1	50·9	+ 3·4	− 0·4
10	24·5	16·9	21·8	28·1	22·8	41·5	− 2·9	− 9·8
11	23·2	*23·8	20·9	23·6	22·9	23·9	− 2·8	− 27·4

In the above table the sun-spot maximum occurs in the 5th group, and the rainfall is made to be 1·2 inch below the mean; that is, according to this arrangement the people of Edinburgh are supposed to get *less* than their average allowance of rain in the maximum year. But according to the observations published by the Scottish Meteorological Society, that again is contrary to fact, for (see Table V.) the rainfall of Edinburgh is not 1·2 inch *below* the mean for the maximum years, but, taking the thirteen "means" five inches *above* it, and, taking the "mean cycle" 3 inches above it.

Which of the two methods, then, is the more applicable to the data for discussion?

Of all the methods, that of the harmonic analysis is doubtless the best. It enables us to see whether there is any parallelism, and if there is a cycle, what is its probable length with respect to the sun-spot cycle, the range of variation, the times of maximum and minimum, with their intervals, &c. I have applied this method to yearly values of the rainfalls, and of the levels of rivers of various countries, and have come to the conclusion that, notwithstanding all apparent irregularities, there is an intimate connection between sun-spots and rainfall.

If the rainfall generally was above its mean in the years of maximum sun-spot, and below it in the years of minimum sun-spot, we should get for the mean yearly rainfall of a number of stations the equation $\frac{S-s}{s'-S}=\frac{R-r}{r'-R}$, where S is the mean value of the sun-spots for the period examined, s the mean value of the spots when below S, s' their mean value when above S, and R, r, r' the corresponding values for the rain for the years from which S, s, and s' were obtained. This formula applied to the public observations of different countries shows that with very few exceptions the rainfall for the periods examined were above the average. The results for the mean rainfall of fifty-four stations in Great Britain, and thirty-four in America from 1824 to 1867 are as follows:—

$$\text{Great Britain} \ldots \ldots \begin{cases} \frac{S-s}{s'-S} = \frac{24\cdot9}{29\cdot8} = \cdot8356 \\ \frac{R-r}{r'-R} = \frac{+0\cdot75}{+0\cdot90} = \cdot8333 \end{cases}$$

$$\text{America} \ldots \ldots \ldots \begin{cases} \frac{S-s}{s'-S} = \frac{24\cdot9}{29\cdot8} = \cdot8356 \\ \frac{R-r}{r'-R} = \frac{+0\cdot94}{+1\cdot13} = \cdot8407 \end{cases}$$

In other words, the rainfall of fifty-four stations in Britain from 1824 to 1867 was 0·75 inch below the mean when the sun-spots were below their mean and 0·90 inch above it when the spots were in excess, and the corresponding values for America were 0·94 and 1·13 inch.

C. MELDRUM

Sun-spots and Weather

IN NATURE, vol. xvii. p. 326, Dr. Balfour Stewart concludes an article with the following remark:—

"It is nearly, if not absolutely, impossible from observations already made, to tell whether the sun be hotter or colder as a whole when there are most spots on his surface. The sooner we get to know this the better for our problem."

The Bombay barometric observations appear to me to afford fairly conclusive evidence in favour of the sun being hottest about the time of maximum spotted area, and coldest when the spotted area is at its minimum.

It is well known that in Central Asia the annual variation of the barometric pressure is greater than in any other portion of the globe, and it is universally admitted that this variation is due to the great variation of temperature between summer and winter, the barometer being low when the temperature is high, and *vice versâ*. If, therefore, the absolute heat of the sun is subject to considerable variations, we ought to find the barometric pressure in Central Asia responding to those variations just as it does to the annual variations of temperature; in other words, the summer barometric minimum should be lowest in those years when the sun is hottest, and the winter maximum should be highest in those years when the sun is coldest.

Similar results should be obtainable from the barometric records of any station where the annual variation of pressure is considerable and of the same character as in Central Asia. Bombay is such a station, and one where cyclonic disturbances are less frequent and violent than at most other Indian coast stations. I give below the mean barometric pressure at Bombay for the summer and winter half-years from 1847 to 1877:—

Mean Barometric Pressure at Bombay.

October to March.	1847–48.	1848–49.	1849–50.	1850–51.	1851–52.	1852–53.	1853–54.	1854–55.	1855–56.	1856–57.	1857–58.	1858–59.	1859–60.	1860–61.	1861–62.	1862–63.
	29+ ·884	29+ ·888	29+ ·894	29+ ·886	29+ ·888	29+ ·891	29+ ·891	29+ ·897	29+ ·905	29+ ·901	29+ ·898	29+ ·901	29+ ·894	29+ ·886	29+ ·886	29+ ·862
	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	1869–70.	1870–71.	1871–72.	1872–73.	1873–74.	1874–75.	1875–76.	1876–77.	1877–78.	—
	29+ ·885	29+ ·912	29+ ·902	29+ ·906	29+ ·925	29+ ·913	29+ ·903	29+ ·872	29+ ·879	29+ ·878	29+ ·897	29+ ·906	29+ ·893	29+ ·903	29+ ·916	— —
April to September.	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
	29+ ·707	29+ ·722	29+ ·703	29+ ·730	29+ ·704	29+ ·719	29+ ·737	29+ ·712	29+ ·743	29+ ·712	29+ ·718	29+ ·723	29+ ·729	29+ ·722	29+ ·707	29+ ·705
	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	—
	29+ ·698	29+ ·751	29+ ·720	29+ ·738	29+ ·722	29+ ·760	29+ ·726	29+ ·721	29+ ·731	29+ ·713	29+ ·725	29+ ·713	29+ ·722	29+ ·723	29+ ·773	— —

The winter means correspond in time to the beginning of each year, the summer means to the middle of each year. Taking the mean of each pair of winter means, we obtain a new set of numbers which correspond to the middle of each year, and which give a somewhat smoother curve than the original numbers, and performing a similar operation twice upon the summer means, we obtain a similarly smoothed set of numbers also corresponding to the middle of each year. These two sets of smoothed numbers, and their means, are given below, and graphically represented by the accompanying curves, along with the inverted sun-spot curve.

—	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Winter	29+ ·886	29+ ·891	29+ ·890	29+ ·887	29+ ·889	29+ ·891	29+ ·894	29+ ·901	29+ ·903	29+ ·899	29+ ·899	29+ ·897	29+ ·890	29+ ·886	29+ ·874
Summer	·713	·714	·716	·714	·719	·726	·725	·727	·721	·717	·723	·725	·719	·710	·703
Year	·799	·802	·803	·800	·804	·808	·809	·814	·812	·808	·811	·811	·804	·798	·788
—	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
Winter	29+ ·873	29+ ·898	29+ ·907	29+ ·904	29+ ·915	29+ ·919	29+ ·908	29+ ·887	29+ ·875	29+ ·878	29+ ·887	29+ ·901	29+ ·899	29+ ·898	29+ ·909
Summer	·712	·729	·732	·729	·735	·742	·733	·724	·724	·720	·719	·718	·719	·735	[·773]
Year	·792	·813	·819	·816	·825	·830	·820	·805	·799	·799	·803	·809	·809	·816	[·845]